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# Alcohol consumption by aging adults in the United States: Health benefits and detriments

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**Abstract** The most rapidly growing segment of the US population is that of older adults ( $\geq 65$  years). Trends of aging adults (those aged  $\geq 50$  years) show that fewer women than men consume alcohol, women consume less alcohol than men, and total alcohol intake decreases after retirement. A U- or J-shaped relationship between alcohol intake and mortality exists among middle-aged (age 45 to 65 years) and older adults. Thus, alcohol can be considered either a tonic or a toxin in dose-dependent fashion. Active areas of research regarding the possible benefits of moderate alcohol consumption among aging individuals include oxidative stress, dementia, psychosocial functioning, dietary contributions, and disease prevention. Yet, due to the rising absolute number of older adults, there may be a silent epidemic of alcohol abuse in this group. Dietary effects of moderate and excessive alcohol consumption are reviewed along with mechanisms by which alcohol or phytochemicals modify physiology, mortality, and disease burden. Alcohol pharmacokinetics is considered alongside age-related sensitivities to alcohol, drug interactions, and disease-related physiological changes. International guidelines for alcohol consumption are reviewed and reveal that many nations lack guidelines specific to older adults. A review of national guidelines for alcohol consumption specific to older adults (eg, those offered by the National Institute on Alcohol Abuse) suggests that they may be too restrictive, given the current literature. There is need for greater quantification and qualification of per capita consumption, consumption patterns (quantity, frequency, and stratified combinations), and types of alcohol consumed by older adults in the United States.

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There is growing evidence that moderate alcohol (ethanol) intake is associated with reduced mortality and disease burden among middle-aged (45 to 65 years) and older (aged  $>65$  years) adults in industrialized societies, such as the United States. An intake of one to three daily alcoholic drinks generally corresponds to this window of health opportunity in populations. Despite these population-based associations, medical and health professionals should be mindful that among some individuals, the risks of moderate drinking outweigh the benefits. Physicians and registered dietitians, together with the rest of a health care team, can assess an individual's health, medications, and family history for advisement regarding alcohol use. Herein is a summary of the current literature regarding the beneficial and detrimental effects associated with alcohol consumption among aging adults (those aged 50 years and older). Covered topics include alcohol pharmacokinetics, psychosocial and dietary effects, mortality and disease burden, alcohol consumption guidelines, and future directions for research.

Figure 1 highlights results from illustrative key studies on some of these topics

Older adults comprise a rapidly growing segment of the US population (8). Drinking trends of both the general and older adult populations in the United States indicate that more men than women consume alcohol, men consume more than women, and total intake decreases after retirement (9). Increasing morbidity in older adults may explain the age-related decline in alcohol consumption observed after retirement (10). The prevalence of current drinkers aged 60 years and older who consume one daily drink in the United States is 16% of women and 25% of men, according to a recent nationally representative cross-sectional survey (11). In the United States, one standard drink provides approximately 15 g ethanol; the amount in 355 mL (12 fl oz) regular beer, 150 mL wine (5 fl oz), or 45 mL (1.5 fl oz) 80-proof distilled spirits. The majority of women and men (aged 60 years or older) who are current drinkers in the United States are moderate drinkers, as defined by US dietary guidelines (11).

Participant Profile	Study Design	Association with alcohol intake
1999-2000 National Health & Nutrition Examination Survey: 1,933 adult women & men aged ≥ 51 y	Cross-sectional	Nondrinkers and current drinkers had better diet quality (Healthy Eating Index) compared to younger persons. Analyses including all ages (>20y; n=3,729) indicate that diet quality was best among frequent consumers of moderate alcohol (e.g. 1 to 2 daily drinks) (1).
United States & British cohorts: 13,333 older adult women & men aged ≥ 65y	4 to 5y Prospective	Moderate drinking (1 to 2 daily drinks) associated with decreased mortality and indices of disability compared to abstainers (2).
Cardiovascular Health Study cohort: 5,865 older adult women & men aged ≥ 65y	12y Prospective	U-shaped association between alcohol intake and risk of hip fracture; positive relationship of alcohol intake with hip bone density among drinkers of 14+drinks/week compared to abstainers (3).
1,015,835 adult women & men across 34 studies	Meta-analysis	J-shaped association between alcohol intake and mortality in adults. Protective doses appear to be 1 to 2 daily drinks for women and 2 to 4 daily drinks for men (4).
13 cohorts of adult women & men	Meta-analysis	U-shaped association between alcohol intake and type 2 diabetes in adults. 30% risk reduction in women and men consuming 6 to 48g/d ethanol (0.5 to 3 daily drinks) (5).
Cardiovascular Health Study cohort: 4,410 older adults aged ≥ 65y	9.2y Prospective	Moderate drinking (~14 drinks/week) associated with the lowest risk of coronary heart disease compared to abstainers (6).
Washington Heights Inwood-Colombia Aging project: 980 older adults aged ≥ 65y	4y Prospective	Moderate intake (≤3 daily drinks) of wine associated with lower risk of Alzheimer's disease as compared to abstainers (7).

**Figure 1.** Results of some meta-analyses and large prospective studies of alcohol intake and mortality/disease.

Heavy episodic drinking, a measure of higher risk drinking, decreased among increasingly older adults with 5% and 18% of women and men (aged 60 years or older), respectively, currently engaged in heavy episodic drinking, according to a cross-sectional National Health Interview Survey analysis (11). Chan and colleagues (9) provide recent age- and sex-specific norms on alcohol consumption rates and patterns for educational use with older adults. Current research findings regarding alcohol consumption by older adults range from the beneficent effects associated with moderate intakes, to the deleterious effects associated with immoderate intakes.

## ALCOHOL PHARMACOKINETICS

Ethanol ( $C_2H_5OH$ ) is a physiologically nonessential, energy-yielding (29 kJ/g or 7 kcal/g) molecule produced by alcoholic fermentation of pyruvate from plants with high carbohydrate content (eg, barley, wheat, corn, and grapes). The

principal source of dietary ethanol is beer, distilled spirits, and wine, whether consumed as a beverage, or added during food preparation. Ethanol does not require gastrointestinal digestion, and may undergo first pass metabolism (FPM) by gastric alcohol dehydrogenase (ADH). Approximately 2% of ethanol undergoes FPM by gastric ADH (12). Adult men have greater gastric ADH activity than women; thus, alcohol bioavailability in men is reduced relative to that in adult women (13). In older adults, gastric ADH activity is significantly reduced (14), potentially increasing ethanol bioavailability with age. Alcohol that does not undergo FPM by gastric ADH diffuses across the stomach and proximal intestine to enter the portal circulation.

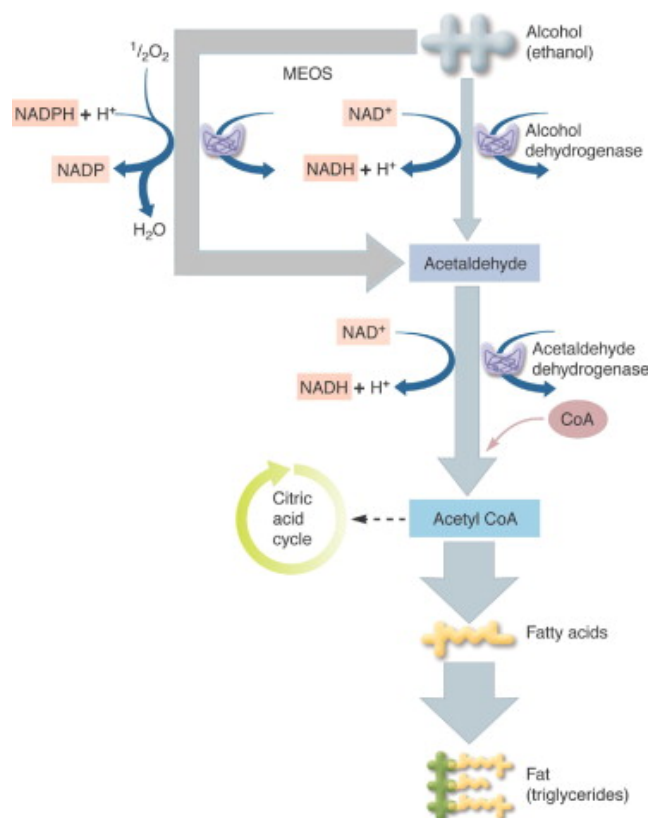
The hepatocyte is the primary site of ethanol metabolism (15). Hepatic ADH is the rate-limiting, noninducible cytoplasmic enzyme that oxidizes alcohol to acetaldehyde, capturing reducing equivalents as reduced nicotinamide adenine dinucleotide ( $NADH+H^+$ ) by the coenzyme

oxidized nicotinamide adenine dinucleotide ( $\text{NAD}^+$ ).  $\text{NAD}^+$  is in limited supply and must be regenerated.

The detoxification rate of ethanol by hepatic ADH is thus limited to a processing rate of approximately 15 g/hour (16). Alternatively, biotransformation of ethanol can occur via Phase I reactions in the smooth endoplasmic reticulum in most cells by the nonspecific, inducible microsomal ethanol-oxidizing system (MEOS), catalyzed by monooxygenases (17). Figure 2 illustrates the ADH and MEOS pathways of ethanol metabolism (18). Induction of MEOS allows for greater processing of alcohol than by ADH alone, and will enhance metabolism of apolar compounds in the body. Drugs and nutrients may be cometabolized, potentially leading to situations ranging from adverse drug reactions (19, 20 and 21), vitamin deficiency (eg, retinol) (22 and 23), and reactive oxygen species (ROS) formation (16 and 20). Thus, health care teams should consider the implications of alcohol and medication interactions, especially in older adults.

Maximal blood alcohol concentrations (BAC) are reached approximately 45 to 75 minutes after an oral dose of alcohol in 20- to 60-year old men (24). There is no reported sex difference in time to maximal BAC up to age 55 years (25). However, it is not clear if sex differences exist in maximal BAC. Gubala and colleagues (25) report lower maximal BAC in women than men (aged 21 to 55 years), while Baraona and colleagues (13) report a higher maximal BAC in women than men (aged <50 years). Differences in the models used to determine alcohol pharmacokinetics may explain disparate BAC observations. Future work should clarify the effect of sex on alcohol pharmacokinetics across the lifespan.

Body composition is altered by aging and this influences BAC. Whereas young adult body mass is approximately 70% water, by age 65 years, body fat doubles in men and increases by 50% in women (19) resulting in reduced total body water and interstitial fluid volume with age. Ethanol is readily solubilized in water because the hydroxyl group of ethanol allows formation of hydrogen bonds with water. Thus, it is quickly distributed across all aqueous spaces, including



**Figure 2.** Metabolism of ethanol: alcohol dehydrogenase and microsomal ethanol oxidizing system (MEOS) pathways.  $\text{O}_2$ =Oxygen.  $\text{H}$ =Hydrogen.  $\text{H}_2\text{O}$ =Water.  $\text{CoA}$ =Coenzyme A.  $\text{NAD}^+$ =Oxidized nicotinamide adenine dinucleotide.  $\text{NADH}$ =Reduced nicotinamide adenine dinucleotide.  $\text{NADP}$ =Nicotinamide adenine dinucleotide phosphate.  $\text{NADPH}$ =Reduced nicotinamide adenine dinucleotide phosphate. Adapted with permission from reference 18.

solid substances and structurally bound water, extracellular spaces, and intracellular spaces (20). The reduced ratio of interstitial to intracellular water volume in aging adults (20) compromises ethanol distribution raising BAC relative to a similar dose consumed in a younger person of the same body mass.

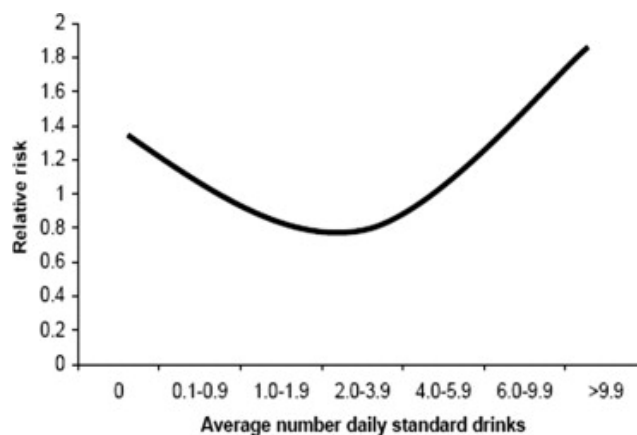
## BENEFITS OF MODERATE ALCOHOL CONSUMPTION

Like most drugs, ethanol can be considered either a tonic or a toxin in dose-dependent fashion, and this appears to hold true in older adults as well. Moderate alcohol consumption—the only volume/pattern of consumption that confers pos-

sible health benefits in populations—has not been consistently defined across studies (26) or by government agencies. For example, in Canada, moderate drinking for both women and men is intake of approximately 30 g ethanol total (two standard drinks per day), as delineated by the Centre for Addiction and Mental Health (27). Moderate alcohol consumption, as defined by the US Department of Health and Human Services, and the US Department of Agriculture (USDA), is no more than 14 g/day ethanol (one standard drink) for women and no more than 28 g/day ethanol (two standard drinks) for men. In Europe, one standard drink generally provides 10 g ethanol whereas in Japan, one standard drink provides 20 g ethanol. In this review, a standard drink will refer to an alcoholic beverage that provides 15 g ethanol, the amount of ethanol that can be processed by the hepatic ADH system per hour (16). Moderate alcohol consumption herein will refer to the intake of one to three standard drinks per day (15 to 45 g ethanol), unless otherwise stated. Immoderate alcohol consumption will refer to those dosages of alcohol intake, beyond moderation, associated with increased relative risk of mortality/disease (>3 standard drinks; >45g/day ethanol). These working definitions are mindful of both the current USDA guidelines, and the international body of research literature that supports the range of alcohol intake at which health benefits outweigh health risks. However, it should be recognized that definitions are not standardized and need refinement.

Epidemiologic data from more than 100 studies across 25 countries consistently demonstrate a U- or J-shaped association between alcohol consumption and coronary heart disease (28). Data suggest that benefits are conferred by moderate consumption of alcohol, perhaps regardless of beverage type (eg, wine, beer, or distilled spirits), for reduction of coronary heart disease risk (29) in older adults (6). The relationship holds for mortality (4). Current findings suggest that this U-shaped relationship between alcohol intake and mortality exists among middle-aged and older adults, as determined by a large prospective study in Denmark (30), and in the United States (31). Another large prospective study of middle-

aged and older adult US men corroborates these results (32). The U- or J-shaped curve in Figure 3 depicts the risk reduction of early death among aging drinkers (Danish women and men aged >50 years), relative to the risk in abstainers and in those who consume more than an average of four drinks per day (30).



**Figure 3.** Alcohol consumption and relative risk (RR) of mortality in Danish women and men older than age 50 years. RR is the ratio comparing the probability of mortality/disease in drinkers with the probability of that outcome in non-drinkers (RR<1 indicates decreased risk, RR=1 indicates no difference in risk, and RR>1 indicates increased risk). Adapted with permission from reference 30.

There are numerous studies indicating a positive influence of moderate alcohol intake on cardiovascular risk factors and incidence (33, 34 and 35). In a population study of 53- to 74-year-old men, Hein and colleagues (36) reported an inverse association between alcohol intake and the risk of ischemic heart disease. Rimm and colleagues (37) reported that after adjustment for coronary risk factors (including dietary cholesterol, fat, and fiber) alcohol intake was inversely related to coronary heart disease incidence. More recent studies present additional data consistent with this earlier evidence (38, 39 and 40). Results from a randomized controlled trial reported by Davies and colleagues (41) suggest that consumption of 30 g/day ethanol (two standard drinks) meliorates triglyceride concentrations and insulin sensitivity in nondiabetic postmenopausal women. Moderate intake of alcohol (less than three drinks per day) by diabetic men (aged

40 to 75 years) is associated with lower levels of markers of inflammation and endothelial dysfunction (42); lowered risk of cardiovascular disease may occur through such mechanisms (43).

There is research to suggest that alcohol/wine can exert protective effects against other diseases such as cancer (44), diabetes (2 and 5), inflammatory liver disease (45 and 46), and lower extremity arterial disease (47). A prospective study of women (aged 33 to 55 years) was reported by Knight and colleagues (48) to investigate alcohol intake and renal function during an 11-year period. Moderate alcohol intake (5 to 15g/day ethanol) was not associated with reduced renal function in these women. There are reports of positive effects of alcohol/wine intake on bone density in elderly women (3 and 49). Garry and colleagues (50) report that moderate alcohol consumption (11 to 29 g/day ethanol) by French women (aged 75 years or older) is positively associated with trabecular bone mineral density.

Alzheimer's disease and vascular dementia are public health concerns in the aging Western population (26). Ethanol and acetaldehyde are toxins that negatively affect neural tissues. Chronic immoderate ethanol intake is associated with increased risk of alcohol-related central nervous system disease (51) and dementia in elderly persons (26). Although the toxic effects of immoderate alcohol intake on the central nervous system are well known, there are emerging data to suggest that moderate alcohol intake (eg, one to three drinks per day) is associated with a reduced risk of developing Alzheimer's disease (52, 53, 54 and 55) and vascular dementia (55 and 56). Carriers of the apoE4 allele, a marker of dementia development, achieve risk reduction with an alcohol intake at the lower end of the moderate range (eg, one drink per day) (57). Apparently the association differs across the alcohol beverage type (ie, beer, wine, and distilled spirits) consumed in moderation; wine may confer protective modulation whereas beer may confer negative modulation for risk of dementia (7 and 55). Due to the expected increase in number of aging women and men in the population, additional research regarding the influence of alcohol consumption upon dementia and cognitive function-

ing could provide important clarification for these emergent findings (26).

## PSYCHOSOCIAL BENEFITS OF MODERATE ALCOHOL CONSUMPTION

The potential benefit that moderate drinking may have upon psychosocial functioning (58) is an underappreciated inquiry; specifically in relation to improved appetite and dietary consumption in older adults. In many societies, drinking provides a means for friends and family to gather, relax, eat, and enjoy each other's company. Worldwide, aging women and men experience varying degrees of loss, decreased finances, loneliness, and reduced mobility and independence—all of which can contribute to a cycle of isolation that reduces social contact that otherwise may enhance the enjoyment of food and nutritional well-being. The literature is replete with studies regarding the physiological and psychological effects of alcohol abuse. The relative paucity of literature on the potential benefits of moderate alcohol consumption on mental and social well-being should entice further work in this area. Many physicians and registered dietitians suggest, for their patients, a glass of wine (150 mL) with meals for appetite stimulation and improved dietary intake; specific research needs to substantiate this claim (59). Moderate alcohol intake (fewer than three drinks per day) was found to be prevalent among residents of three US retirement communities and was associated with improved social interactions and self-reported health status (60). Among elderly Australian women (aged 70 years and older), moderate alcohol consumption (one to two drinks per day) was found to be positively associated with health-related quality of life and survival (61). Abstinence and infrequent alcohol consumption (adjusted for comorbidities) were found to be negatively associated with health-related quality of life and survival in this cohort of women. Whether improved social interactions are associated with meliorated dietary intake and quality, and whether alcohol intake is associated with these outcomes, warrants future investigation.

## DIETARY BENEFITS OF MODERATE ALCOHOL CONSUMPTION

Little emphasis has been placed on the dietary context of alcohol consumption among aging adults. Research focused on moderate alcohol intake in older adults suggests some positive influences on energy intake and health. One study has assessed alcohol intake in US adults, including those older than age 50 years, with a focus on total diet quality (1). Measures of alcohol intake in dietary analyses in US populations have taken several forms, including measures of foods, food groups, nutrients, and diet quality (1, 62, 63, 64, 65, 66, 67 and 68). Alcohol consumption is typically determined using quantity consumed (grams of ethanol), frequency of consumption, average volume (quantity multiplied by frequency), and stratified combinations of consumption and frequency. Moderate alcohol intake and its relationship to total energy intake and health continue to be areas of interest and needed study among aging adults.

Rose and colleagues (67) reported a significant increase in total energy intake across groups of US adults identified as none, light, moderate, or heavy (more than two drinks per day) consumers of alcohol, without differences in food energy intake, across these groups. Kim and colleagues (65) also demonstrated in a recent cross-sectional survey of US adults that energy intake significantly increased with increasing alcohol intake. According to a recent review, the consumption pattern of alcohol intake may affect energy intake (69). A compensatory reduction in food intake has been reported in association with alcohol intake at a meal, or up to an hour before the meal (69). Further research on this equivocal topic is needed.

Future investigations should clarify the effects of alcohol consumption patterns on diet quality endpoints. This can be achieved by reporting alcohol intake as stratified measures of frequency and quantity of consumption. Summary measures such as average volume consumed (grams of ethanol) may obscure important associations (1) that would contribute to our understanding of the independent and joint influ-

ences of quantity and frequency of alcohol consumption on diet quality (eg, as measured by the USDA Healthy Eating Inventory). Breslow and colleagues (1) demonstrated in adjusted analyses (for sex, age, race, education, smoking, body mass index [BMI], and leisure physical activity) that frequency and quantity of alcohol consumption had opposite associations with diet quality, as measured by the USDA Healthy Eating Inventory. It was established that drinking more alcohol per occasion was associated with decreased diet quality, whereas frequent drinking of small amounts was associated with improved diet quality (1).

The study of the effects of alcoholic beverage-associated phytochemicals on dietary quality and health outcomes is another area of research interest. Oxidative stress is implicated in the pathology of many lifestyle-related diseases associated with aging (70, 71 and 72), such as cardiovascular disease, cancer, and diabetes mellitus. Epidemiologic studies demonstrate a positive correlation between increased consumption of antioxidant-rich, plant-derived foods/beverages and reduced risk of heart disease and certain cancers (73). Many alcoholic beverages contain phytochemicals that may confer protective antioxidant properties. Polyphenols are among the most widely distributed of these phytochemicals. The average dietary intake of polyphenols is 200 mg/day, and the human absorption and metabolism of free and conjugated forms of phenolic acids has been demonstrated for both foods and beverages, including beer (74).

Lugasi and Hovari (73) recently assessed various wines (red and white) and beers (lager and dark) for polyphenol content and antioxidant capacities. They found polyphenol concentrations high in red wines (approximately 1,000 mg polyphenols.L<sup>-1</sup>), and lower in beers and white wines (approximately 400 mg polyphenols.L<sup>-1</sup>). While in vitro antioxidant activity in the tested beverages was found to be commensurate with total polyphenol content in that study, it has been hypothesized that in vivo antioxidant capacities of beer and red wine may be similar despite different concentrations of total polyphenols (75). Future research should help determine whether there are



bioavailability differences (eg, effects of absorption) (74, 75, 76 and 77) associated with differential polyphenol or alcohol profiles across the beverage categories (eg, wine vs beer). Hops are a rich source of isohumulones in beer (75), whereas red wine is rich in other polyphenols (eg, resveratrol) that are not highly represented in white wine (77). More studies are needed to clarify the relationship between alcoholic beverage-associated phytochemicals and health outcomes.

### **EFFECT OF MODERATE ALCOHOL CONSUMPTION ON BODY MASS / COMPOSITION**

The relationship between alcohol consumption and body mass/composition is controversial (63). In an analysis of 3-day food records from a large (N=5,866) stratified random sample of US adults (aged >19 years), Rose and colleagues (67) report that despite a significant association of increased energy intake across increasing levels of alcohol intake, BMI was not increased in women who drank more. Men categorized as heavy drinkers (more than two drinks per day) did have a higher BMI than light drinkers (up to one drink per day) (67). More recently, Breslow and colleagues (78) pooled cross-sectional data from the 1997-2001 National Health Interview Surveys in the United States and determined that regardless of the amount of alcohol consumed, there is a strong pattern of decreasing BMI with increasing frequency of consumption. Although frequent consumers of larger amounts of alcohol were obese, nondrinkers and the lowest quintile of frequent drinkers (one drink per day) had the lowest BMI. This suggests that prevention of weight gain from alcohol consumption is associated with regular drinking of small or moderate portions. These findings are important because only non-smokers were analyzed, thus eliminating the confounding effects of smoking. Westerterp and colleagues (79) addressed the association between alcohol intake and total energy expenditure in aging adults (mean age 61±5 years) and found a significant positive correlation between the habitual level of alcohol intake and physical activity, as measured by 7-day food records and triaxi-

al accelerometry, respectively. The findings that dietary energy is supplemented, not displaced, by alcohol energy without weight gain may be explained by the association between increased habitual physical activity and alcohol intake (79). This hypothesis warrants corroboration by future research regarding the contribution of the pattern of ethanol consumption to energy intake, energy expenditure, and indexes of body composition in healthy older adults.

### **DETRIMENTS OF IMMODERATE ALCOHOL CONSUMPTION**

Although moderate consumption of alcohol, as previously defined, may be associated with certain health benefits, immoderate alcohol consumption accounts for high levels of mortality, morbidity, and social malaise in the United States (26). Worldwide, alcohol abuse is expected to take an increasing toll on lives and communities (80, 81 and 82). Global patterns and volumes of alcohol consumption are increasingly more harmful and risky. More older adults are likely to present with unhealthful alcohol consumption patterns/volumes, because this segment of the global population will increase from 11% to 25% of the population within the next 25 years (26).

Alcohol abuse and alcoholism (83) may be an underrecognized problem in aging adults despite the overall decrease in alcohol consumption with increasing age (10). Due to the absolute increase in the number of aging persons with alcohol-use disorders worldwide, a silent epidemic may be emerging (84). There are characteristically distinct subgroups of alcoholics among problem drinkers older than age 60 to 65 years (85). Approximately two thirds of older alcoholics have been abusing alcohol for some unspecified amount of time, and are termed early onset alcoholics (86). One third of older alcoholics are late onset due to diagnosis after age 70 years (86), attributed to the accumulated stresses associated with aging (51 and 87).

Despite overall decrements of alcohol consumption among the aging, clinicians should be alert for possible misdiagnosis of patient symp-

toms in the clinical setting due to increasing absolute numbers of aging adults. Screening instruments, diagnostic criteria, and recommendations for abstinence specific for the elderly population are in need of refinement (84). The physiological changes and chronic diseases associated with aging complicate the effects of excessive alcohol intake on mortality risk (26). Criteria for alcohol dependence/abuse in the older adult population are provided by the World Health Organization International Classification of Diseases–10 (83). The CAGE questionnaire can be used as an effective screening tool with older adults, with some limitations (83 and 84). The Michigan Alcoholism Screening Test–Geriatric Version is a specific screening tool recommended for use with older adults (88).

Another detriment associated with chronic immoderate intake is oxidative stress, which is implicated in the pathology of many lifestyle-related diseases (70, 71 and 72), including cancer, cardiovascular disease, and diabetes mellitus. Oxidative stress occurs when there is an imbalance between anti-oxidant defense systems and the production of ROS (89). These reactive molecules are generated in response to the metabolism of ethanol by the MEOS enzyme system (90 and 91), and are characterized by having an unstable, unpaired electron configuration. In the process of scavenging electrons for stabilization, ROS oxidize body proteins, lipids, and nucleic acids. Effects of ROS formed during alcohol metabolism are attributed to the development of chronic diseases, including alcohol myopathy (92) and alcoholic liver disease (51 and 93).

Chronic immoderate intake of alcohol damages liver tissue. While upper limits for alcohol intake are not established, a toxicity threshold might be considered to be 50 to 60 g/day ethanol (eg, three and a half to four standard drinks per day) (15). It is generally accepted that intake beyond this range increases the risk for fatty liver development. Individual thresholds vary based on body composition, age, sex, health status, and medications (45). Fatty liver, or steatohepatitis, is the first stage of liver disease. Fatty liver occurs in part because immoderate doses of alcohol produce  $\text{NADH} + \text{H}^+$ , which inhibits oxidative me-

tabolism, so that acetyl coenzyme A is shunted toward fatty acid (Figure 2) and cholesterol synthesis. Liver fat content can increase from a normal value of approximately 5% fat to more than 50% fat (15), but is reversible upon abstinence.

Continued alcohol abuse leads to hepatitis (45) and subsequently to cirrhosis. Cirrhosis is characterized by irreversible replacement of functioning hepatocytes with fibrous connective tissue and is attributed to the toxic effects of ethanol, acetaldehyde, ROS induction, and production of proinflammatory cytokines (45). Cirrhosis results in a variety of hepatic aberrations, including a reduction in protein synthesis, blood flow, bile production, and alcohol metabolism. Progressive deterioration of healthy liver functioning to a diseased organ state may ultimately lead to end-stage liver disease (45) or hepatic carcinoma (89). Yet, there is evidence to suggest that acute moderate alcohol doses (fewer than two drinks per day) appear to have opposite effects on cytokine inflammatory pathways (45 and 46). Further investigation on possible benignant effects of moderate alcohol consumption on the liver is warranted.

## DIETARY EFFECTS OF ALCOHOL ABUSE

Ethanol is an energy-yielding molecule that is not physiologically required. Thus, it is often classified as a drug rather than as a nutrient, although neither classification is incorrect (94 and 95). Perhaps it could be considered a drug when used in immoderate doses, and as a nutrient when used in moderation as part of a balanced diet. Ethanol is energy dense (29 kJ/g or 7 kcal/g) and can displace nutrient dense foods while contributing excess dietary energy (23) when consumed indiscriminately. This can affect energy and macronutrient balance in the body, potentially interfering with glycogen resynthesis in the liver and skeletal muscles through nonadherence to prudent nutrition guidelines (96 and 97). Triglyceride biosynthesis (Figure 2) as a consequence of chronic immoderate alcohol consumption can contribute to elevated blood triglycerides and low-density lipoproteins.

Aberrations of dietary nutrient status may occur when food is displaced by immoderate alcohol intake (23). Commonly displaced nutrients with alcoholism are B vitamins, notably thiamin and pyridoxine. In a recent cross-sectional investigation of US adults, it was demonstrated that the mean nutrient density for several dietary fatty acids decreased with increasing average volume consumption of alcohol (65). In particular, a reduction in n-3 polyunsaturated fatty acid intake was associated with immoderate alcohol consumption (three or more daily drinks) (65). As well, the requirements for some micronutrients may be increased due to alcohol metabolism (23). Hepatic FPM of alcohol requires increased utilization of the NAD<sup>+</sup> and flavin adenine dinucleotide cofactors, of which niacin and riboflavin are components.

Ethanol is a drug capable of producing toxic effects in dose-dependent fashion. Ethanol and acetaldehyde are chemical toxins that can cause cellular damage. Mucosal alterations by these toxins in the gastrointestinal tract can influence nutrient absorption (98). This would be superimposed upon atrophic gastritis that occurs with aging (99). Alcoholic myopathy, due to exposure to these toxins, would also be superimposed upon sarcopenia, the age-related loss of lean body mass, strength (83), and total energy expenditure. Furthermore, skeletal muscle chronically exposed to ethanol demonstrates atrophy of all muscle fiber types, decreased muscle capillarity, and altered metabolism (96). These changes compromise an important organ system involved in overall body metabolism, daily functioning, and quality of life. Progressive liver function loss with alcohol abuse is associated with reduced bile production. Ensuing nutrition concerns include fat malabsorption, reduced food energy absorption, and micronutrient deficiencies (94).

Metabolism of alcohol generates ROS in the mitochondria during oxidative metabolism and by the MEOS (93). Ensuing oxidative stress leads to an upregulation of endogenous antioxidant systems such as superoxide dismutase, catalase, and glutathione peroxidase (91). Several metal cofactors (eg, zinc, manganese, copper, iron, and selenium) of these antioxidant enzymes

likely have increased rates of recycling. Exogenous antioxidants, such as vitamin E (particularly in the central nervous system), vitamin C, and beta carotene may require dietary attention due to increased use (23) in the face of alcohol-induced oxidative stress.

Ethanol-induced diuresis is due to the suppression of antidiuretic hormone release from the pituitary. It has been estimated that the kidney will produce excess urine on the order of 10 mL/g ethanol ingested (97). Thus, one standard drink (15 g ethanol) can contribute by diuresis 150 mL to urinary output. This can contribute to negative hydration balance in a population with a high prevalence of dehydration (100 and 101).

## CURRENT RECOMMENDATIONS

The International Center for Alcohol Policies has compiled international guidelines designed to alter alcohol consumption behavior in target populations (27). The International Center for Alcohol Policies guidelines reveal a lack of international consensus on the interpretation of the results regarding the alcohol dose associated with health protective benefits (ie, moderation) and there is a paucity of age-specific international guidelines for older adults. Guidelines should reflect the benefits and risks of alcohol consumption in the target population, with an intention to alter relevant drinking behavior through a culturally sensitive message (102).

The USDA Dietary Guidelines for Americans, 2005 recommend that those who choose to drink alcoholic beverages should do so in moderation (103). Generally, public health guidelines are evidence-based. The definition of 'moderate alcohol consumption' should reflect the current literature regarding the range of alcohol doses associated with a conferral of health benefits. A recent meta-analysis indicates that the alcohol dose associated with decreased mortality in adult women and men is one to two drinks per day and two to four drinks per day, respectively (4). The US guidelines on moderate alcohol consumption, however, suggest a lower intake than some international guidelines (eg, International Center for

Alcohol Policies) and may be conservative in light of the literature (104).

Although it has been recommended by the National Institute on Alcohol Abuse and Alcoholism that adults older than age 65 years consume no more than one standard drink per day, regardless of sex (8), emerging findings indicate that people older than 65 years who consumed up to two drinks per day had no greater disability or mortality than those who consumed up to one drink per day (2). Kirchner and colleagues (105) recently corroborated these findings in primary care older adults, showing similar health parameters (eg, perceived health, depressive/anxiety symptoms, and social support) between those who drank one to seven drinks weekly and those who consumed eight to 14 drinks weekly. These findings are important because the results suggest that the current US recommendation of one drink per day for an older adult, by the National Institute on Alcohol Abuse and Alcoholism, may be restrictive.

## CONCLUSIONS

It is important to consider the benefits and detriments of alcohol consumption in the rapidly growing age group of those older than age 65 years. This is the fastest growing segment of the US population, and there is evidence of an age-related decrease in the consumption of alcohol in this age group. Conversely, there is an increase in the absolute number of older adults who abuse alcohol. Health care teams, including registered dietitians, should encourage abstinence from alcohol for those diagnosed with alcoholism. Screening tools for the detection of alcohol-related problems specific for this age group may need refinement. The beneficence of moderate alcohol consumption among aging adults is demonstrated by epidemiologic evidence of reduced risk of all-cause mortality and disease burden. Future research should endeavor to clarify the relationship between disease modulation, alcohol consumption patterns, and types of alcohol consumed by older adults. For older adults who do drink, moderation can be the advisement given by the health care team, upon consideration of

potential alcohol and drug interactions. National guidelines for older adults regarding salutary doses of alcohol associated with moderate alcohol consumption may need refinement.

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